Real-Time Solar Production Estimation and Forecasting
Introduction

Photovoltaic (PV) solar energy is a small but rapidly growing percentage of total electricity production. The output of solar energy from PV power installations is intermittent due to varying atmospheric and weather conditions. This variability makes it difficult to integrate PV power generation into the electricity grid. As the installed capacity of solar grows, this problem will be magnified. There is a clear need for more granular and accurate estimates of the current and future production of PV solar energy installations.

Locus Energy is developing real-time, granular solar production estimates (‘nowcasts’) and forecasts (up to 7 days ahead) that utilities and grid operators can use to optimize production decisions and grid management. These forecasts will be calibrated using data from the distributed solar installations and weather sensors that Locus Energy monitors, in addition to data from government weather sensors. Forecast accuracy will be continuously quantified and refined, enabling the integration of the production forecasts into mission-critical grid operations. Quantified accuracy will be an integral part of the forecast data feed, which will be available through both a web interface and an application programming interface (API).

Technology Overview

The core technology is based off of numerical weather prediction (NWP) models and solar irradiance estimates and forecasts generated by analyzing satellite imagery. These estimates and forecasts are then processed by a sophisticated single-diode photovoltaic model that simulates all of the installed hardware in the target geography. The resulting production nowcasts and forecasts are tuned using data from select solar installations and weather sensors monitored by Locus Energy and data from government-operated weather sensor networks. The production forecasting product will initially be developed for the state of California and the northeastern United States, with expansion to other regions in the United States and internationally as data becomes available and demand materializes. The solar production forecast model estimates current and future solar production in a target region at a granular level (1km x 1km grid). These estimates are generated using the following four components:

1) Solar irradiance forecasts generated by combining cloud motion forecasting using satellite imagery (see Figure 1 below) from the NASA/NOAA GOES satellites with proprietary NWP models using weather forecast data from the National Digital Forecast Database (NDFD). The GOES satellites provide high-resolution images every 30 minutes for each coast of the United
States and the NDFD generates gridded weather forecasts every hour for the United States. These irradiance forecasts are tuned using data from the network of distributed solar installations and weather sensors that Locus Energy monitors as well as the National Oceanic and Atmospheric Administration’s (NOAA) weather sensor network.

<table>
<thead>
<tr>
<th>time $t$</th>
<th>Cloud motion vectors</th>
<th>$t + 30$ minutes</th>
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Fig. 1: Deriving cloud motion vectors from satellite imagery.

2) A **single diode PV hardware model** that enables the conversion of irradiance to power output and vice versa. This proprietary model carries out a detailed simulation in order to accurately model physical hardware (see Fig. 2 below). The underlying technology is similar to the approach that underpins the industry-standard PVSyst and NREL SAM software systems, but is further tuned for each specific hardware type based off of data from the field. Future versions of this model will be able to factor in data on panel/installation age and localized environmental characteristics (climate, dust) gleaned from the network of sites that Locus Energy monitors.

![Graph showing Measured vs. Modeled Total Power Production Over 90 Days (Representative System)](image)

Fig. 2: Quantifying the accuracy of the Locus Energy single diode hardware model.
3) A **database of solar installations** in the region of interest. For California, this database will be based off the California Solar Initiative’s list of solar installations in California with supplemental data from other sources. For other target regions data will be gathered from public utility commissions (PUCs), utilities, and data firms that specialize in collecting solar installation data.

4) **Machine learning techniques** that validate nowcasts and forecasts using real-time PV data and continuously update the forecasts based on evolving ground observations. An example of this approach would be to use real-time data from a solar installation that is shaded by a cloud to determine how that cloud will affect the future production of neighboring systems as it moves. These forecasts can be integrated into mission-critical grid operations because they are continuously validated and forecast accuracy is precisely quantified in real-time using data from the field (see Fig. 3 below for a map of PV installations Locus Energy monitors in California).

![Solar installations monitored by Locus Energy in California.](image-url)
Implementation

Locus Energy has extensive experience building scalable, reliable web-based infrastructure for software services. The core monitoring business consists of 130,000 nodes reporting detailed performance data in intervals of 1 second to 24 hours, and this data is then processed, analyzed, and served to thousands of clients through a web-based fleet management platform and an application programming interface (API). The monitored information serves as the data of record for many clients and is often relied upon operationally for functions including billing and real-time fault and performance monitoring. Locus will apply the same technical know-how gained from building and maintaining the core monitoring system to designing the content delivery mechanism for the solar production forecasts.

Conclusion

Locus Energy is uniquely positioned to build and deploy solar production forecasting because of the specialized knowledge of its research and development team, its exclusive access to a rich, real-time dataset, and its institutional experience providing complex, high reliability data services. Locus anticipates that these solar production forecasts will be a game-changer that will enable much higher penetration levels for distributed solar, and is currently seeking pilot partners in the utility space with whom to collaborate on integration and testing.

About Locus Energy

Locus Energy is a solar monitoring and analytics firm that monitors over 130,000 distributed solar installations across five continents. As a specialist in big data management and analysis in the solar space, Locus Energy conducts cutting-edge research with the objective of facilitating the adoption of renewable energy and enabling significantly higher levels of solar penetration than are currently possible. Solar production forecasts are a core research focus for the firm, and Locus is actively collaborating with academic institutions, national laboratories, nonprofit research foundations, and potential consumers to develop a revolutionary capability in this space. Locus Energy has 30 employees, including 8 dedicated to research and development.